UNITED STATES NAVAL POSTGRADUATE SCHOOL

DEPARTMENT OF THE NAVY ★ NAVAL POSTGRADUATE SCHOOL ★

THESIS

A CONCEPT FOR EXPLOSIVE

ECHO RANGING FOR USE BY ASW HELICOPTERS

by

Harold Nemer

1964

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by

Harold Nemer

Commander, United States Navy

Submitted in partial fulfillment of

the requirements for the degree of

MASTER OF SCIENCE

IN

OPERATIONS RESEARCH

United States Naval Postgraduate School

Monterey, California

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UNCLASSIFIED

~~CONFIDENTIAL~~

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ABSTRACT

The detection of enemy submarines continues to pose a major problem to the United States Navy. Many search systems are in use and many new ideas are being investigated. Helicopter dunking sonar has proven effective but, by its very nature, is extremely heavy and can be used only by large and powerful helicopters. This thesis proposes the use of explosive echo-ranging, with associated light weight equipment, as a means of detecting submarines by helicopters. Some methods of solving the technical aspects are suggested and a logical plan for evaluating the concept is proposed. Typical search plans which can use this method for initial detection are presented with some comments as to their coverage and speed of advance.

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I

INTRODUCTION

1.1 General.

One of the most significant active techniques available to aircraft for the initial detection or redetection of a submerged submarine is explosive echo ranging (JULIE). This technique uses small expendable charges as sources of acoustic energy and hydrophones to pick up reflected signals from submerged objects. These hydrophones are omnidirectional and form part of a floating, receiving/transmitting device called a sonobuoy. These charges and sonobuoys are dropped from the aircraft from an altitude of approximately 500 feet in the vicinity of a suspected submarine contact.

The small charges are detonated in close proximity to the sonobuoys and the signal received by the sonobuoy is transmitted to the aircraft. Equipment in the aircraft displays this signal as range-only information on the target. By a suitable charge pattern the position of the submarine can be ascertained.

1.2 Influences.

The reflected signal, or echo, is influenced by factors relating to the source, the target, and the medium [10]. These can be enumerated as (1) the characteristics of the underwater explosion as an acoustic source, (2) the characteristics of the target submarine, and (3) the influence exerted on these two sets of characteristics by the ocean as a medium of propagation. These factors will not be investigated in this paper. It will be assumed that (1) an underwater explo-

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sion is a suitable sound source, (2) a submarine can produce a detectable echo, and (3) sound waves are successfully propagated through the ocean (with scattering, attenuation, reflection and refraction affecting these waves).

Another influence relates to the characteristics of the particular equipment and doctrines in use with the explosive echo ranging system. These will be investigated as they relate to the concept of explosive echo ranging by helicopters.

1.3 Problem Areas.

As presently used by fixed wing aircraft, the JULIE system has many problem areas. Some of these are:

(1) Sonobuoy positioning. Accurate placement of the sonobuoy is difficult from level flight at 500 feet altitude.

(2) Sonobuoy reliability. A sonobuoy not operating properly must be replaced which requires valuable time.

(3) Bombing accuracy. An accurate distance from the charge to the sonobuoy must be known in order to get a proper plot of the echoes received.

(4) Marker reliability. Sonobuoys are extremely difficult to see from the air and therefore must be marked by suitable devices. If the marker fails to operate, the position of the sonobuoy may be lost and a replacement buoy and marker must then be expended.

(5) Antenna quench. In certain sea conditions the antenna can be momentarily washed over with sea water. This effectively disrupts the transmissions of the sonobuoy.

(6) Transmission loses and atmospheric noise. These serve to

attenuate and mask the transmitted signal.

(7) Receiving difficulties. All the various limitations of receiving radio frequencies of the VHF band apply.

The use of JULIE by fixed wing aircraft and the areas of difficulties are shown in Figure 1.

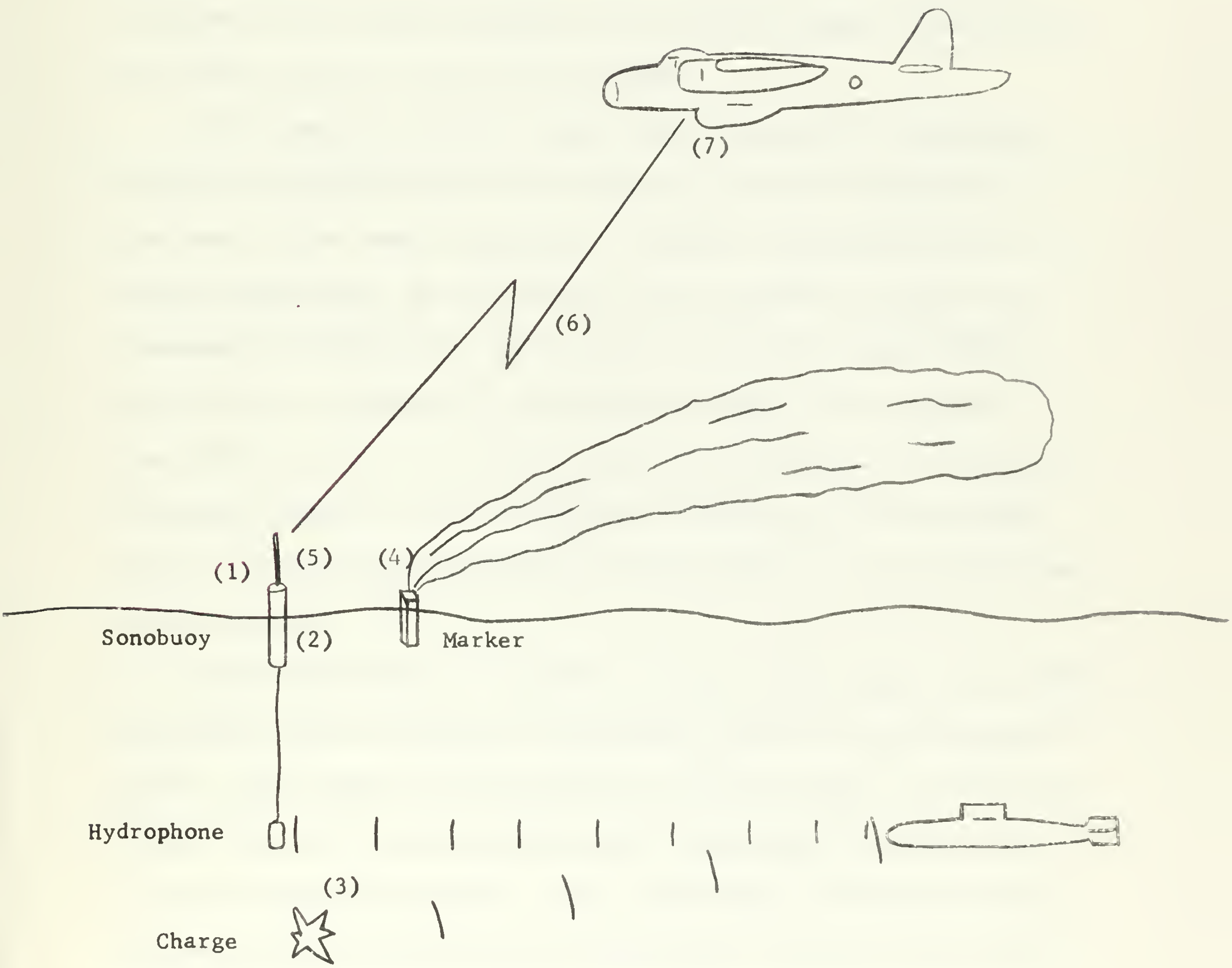

Figure 1

Use of JULIE by Fixed Wing Aircraft

1.4 Application to Helicopters.

At the present time ASW helicopters use only dipped sonar for detection of submerged submarines. This system is very heavy and bulky and requires large and powerful helicopters in which to install the transducer, associated cabling, hoist, and terminal electronic equipment. The time required to hoist the transducer up and down is a function of the desired transducer depth with the speed of hoisting in the order of four or five feet per second.

The frequency at which a dipped sonar operates is a compromise between the maximum size of the transducer and lower attenuations in sea water of the lower frequencies. For water temperatures of 15 degrees Centigrade, the attenuation [11] in decibels per meter at a frequency of 10 kilocycles per second is approximately 100 times as great as at a frequency of 1 kilocycle per second. The pressure spectrum level [10] of the small explosive charges used in echo ranging peaks somewhere in the vicinity of 1 kilocycle per second while most of the dipped sonars operate in the vicinity of 10 kilocycles per second or above.

This thesis proposes to replace the heavy dipped sonar used by ASW Helicopters with an explosive echo ranging system for certain applications. Small charges would provide the acoustic energy to replace the active element of the transducer while a lightweight hydrophone would replace the listening element. Only lightweight, electronic terminal equipment would be required in the helicopter to process the acoustic return from the detonating charge. Figure 2 depicts the proposed explosive echo ranging system.

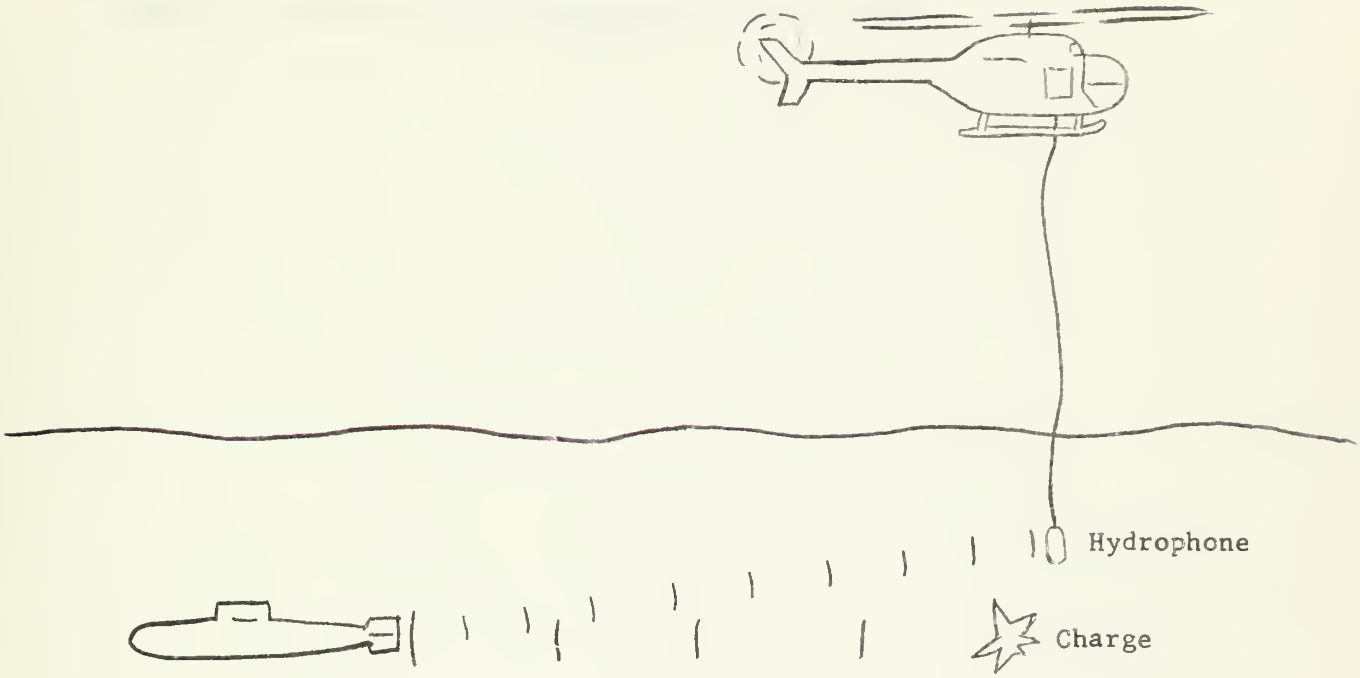

Figure 2

Application of JULIE to a Helicopter

In comparing Figure 1 and Figure 2 it is obvious those areas of difficulty listed for the fixed wing aircraft are not present in the helicopter system. Since the helicopter is free to hover at any position there is no attendant positioning error. The reliability problem with the sonobuoy, antenna quench, transmission loses, and receiving difficulties are eliminated by eliminating the sonobuoy and the VHF link between the sonobuoy and the terminal equipment. No marker devices are required and no bombing accuracies are involved since the helicopter will be hovering directly above the hydrophone at all times.

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Obviously, there will be problems associated with the use of JULIE by helicopters. Some of these problems will be anticipated and possible solutions will be advocated in this paper.

II

DESCRIPTION OF EXPLOSIVE ECHO RANGING

2.1 Area Of Detection Capability.

As previously stated, an explosive echo ranging system provides range-only information on the target. The echoes received are plotted as lines of position. The crossing of two lines of position indicates a fix on the position of the submarine. As will be discussed later, this fix usually is in the form of an ambiguity that must be resolved before the actual position of the submarine is known.

There are two techniques of operation used in explosive echo ranging depending on where the charge is detonated in relation to the hydrophone. If the charge is dropped at the position of the hydrophone it is called an ontop drop. If the charge is dropped at a position away from the hydrophone it is called an offset drop. Usually both techniques are used in conjunction with each other [9]. A circular line of position is obtained from an ontop drop, while an elliptical line of position is obtained from an offset drop.

An idealized picture [2] of the geometry of an ontop drop is presented in Figure 3. When there are no more severe limitations, the maximum range of detection is limited by the depth of the water; this limit is approximately equal to the water depth. Any targets located outside this maximum range are effectively masked by the bottom echo. Under certain conditions it is possible to receive target echoes from outside this maximum range, however, the reliability of such reception is usually too low to be operationally usable.

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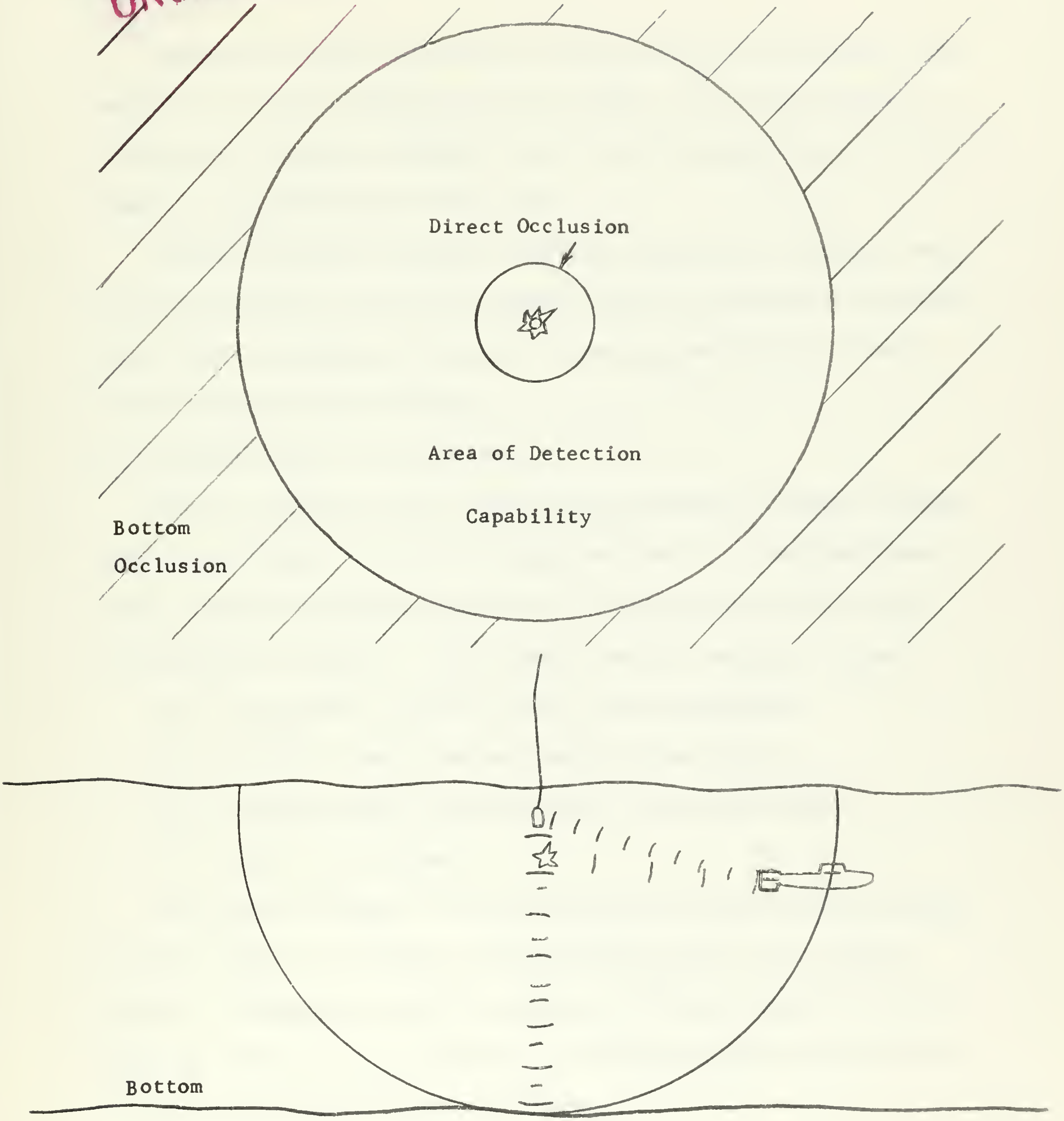

Figure 3

Detection Capability of An Ontop Drop

The area of direct occlusion is caused by the overloading of the system by the direct detonation of the charge. The minimum range of detection is therefore dependent on the type of charge used but can be thought of as approximately 500 yards.

Figure 4 presents a similar idealized picture for an offset drop. Using this method increases the maximum range of detection to distances greater than the depth of the water. However, the direct occlusion area is also greatly increased.

2.2 Physical Basis for Target Plot.

Since an explosive echo ranging system provides no depth information on the target, the plot of target position is a two dimensional plot. The basic physical quantities [1] involved in an offset drop are presented in Figure 5. The symbols used are explained below:

S_c: The distance from the charge to the hydrophone.

R_c: The slant range from the charge to the target.

R_e: The slant range from the target to the hydrophone.

D : Depth of the target.

Also shown in Figure 5 is the plotting error introduced by using the slant ranges to provide a two dimensional plot of the target's position. Assuming a target at a depth of 200 yards below the hydrophone and charge, and at a distance of 2000 yards from the hyrophone, this plotting error is less than 20 yards.

2.3 Mechanics of Plotting.

In Figure 5, the sum $R_c + R_e$ is the distance traveled by the sound producting the target echo. In conjunction with the distance S_c, they

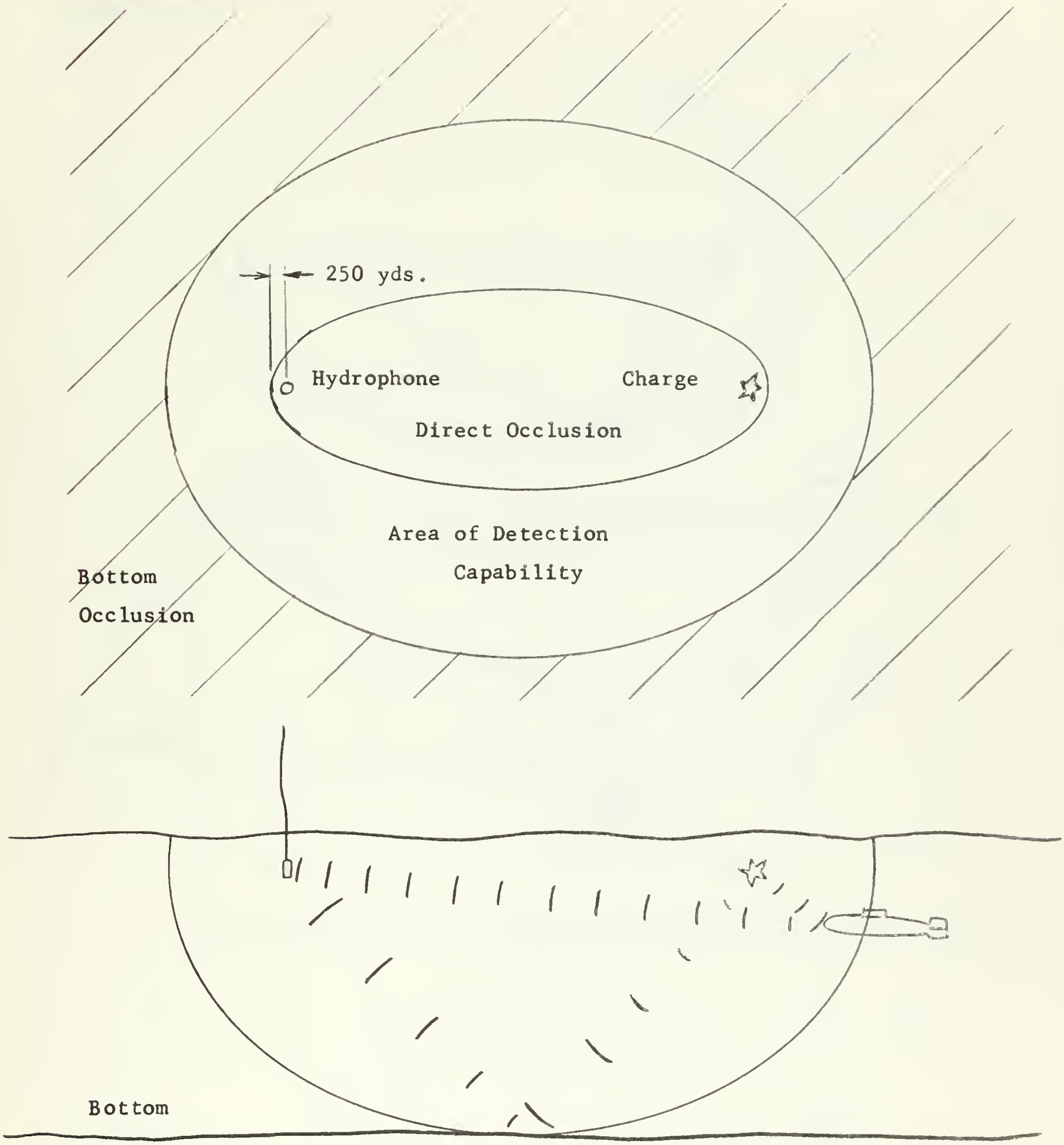

Figure 4

Detection Capability Of An Offset Drop

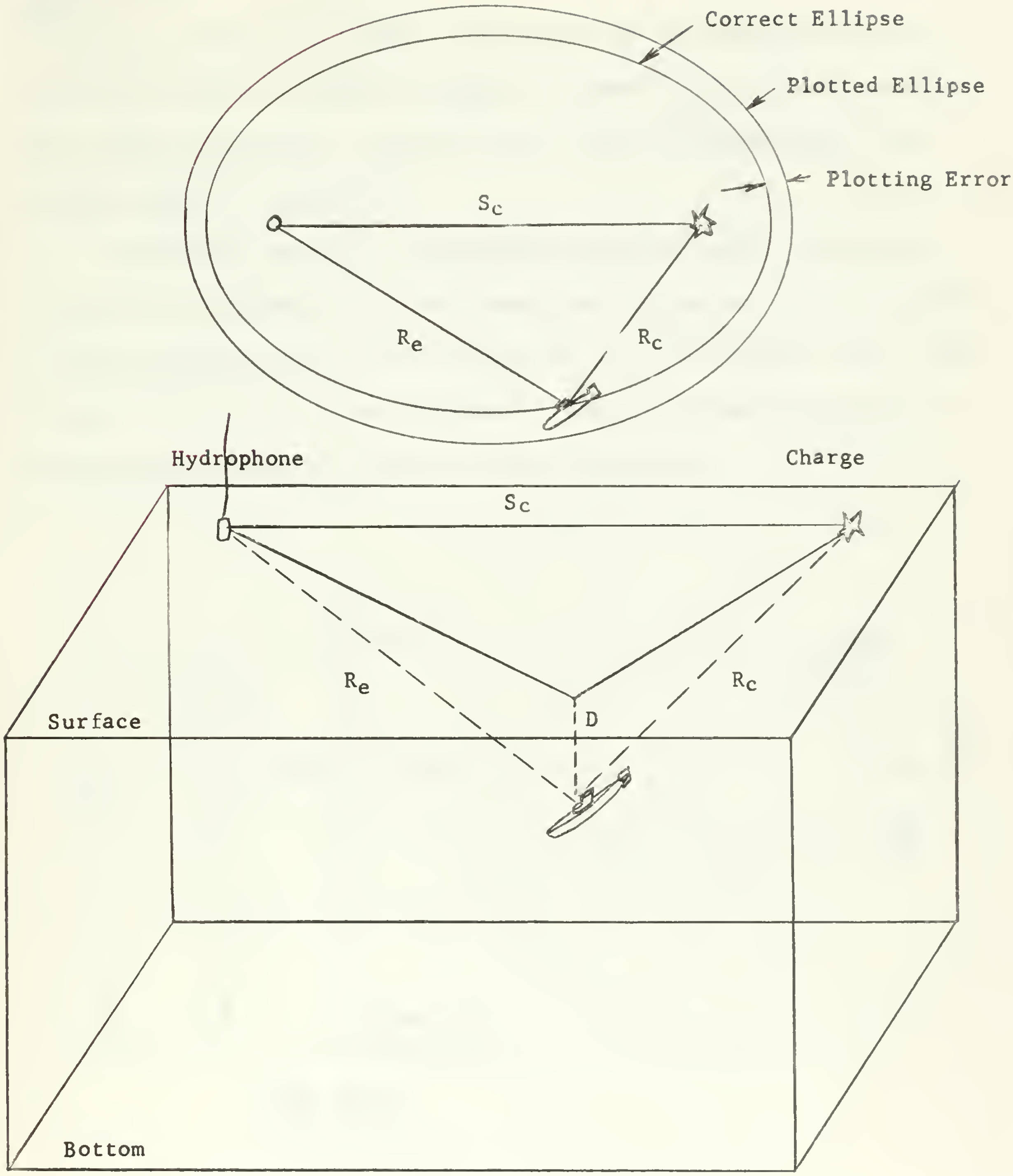

Figure 5

Basic Physical Quantities

And Plotting Error

define an ellipsoid [1], about the charge and the hydrophone as foci, upon the surface of which the target is known to lie. Since submarines have depth limitations, only that part of the ellipsoid above that maximum depth is considered.

As stated previously, a negligible plotting error is introduced if we plot this ellipsoid as a two dimensional elliptical line of position in the horizontal plane. The distance $R_c + R_e$ is obtained from a time trace of the output of the hydrophone. Figure 6 shows the basis for determination of this elliptical line of position.

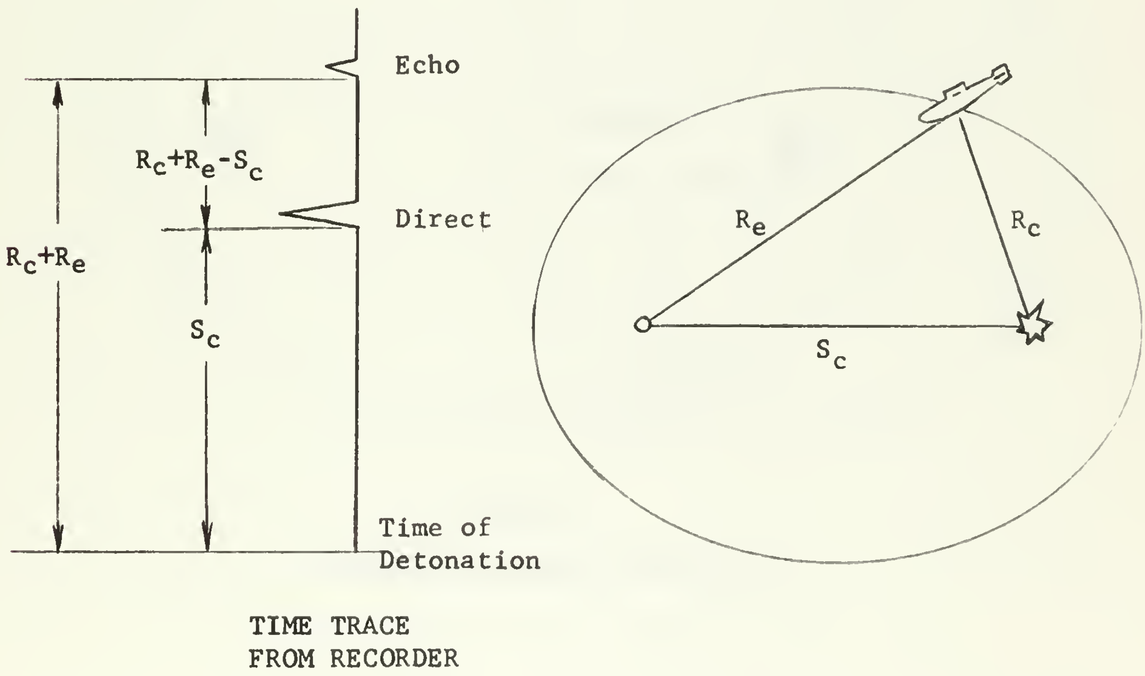

Figure 6

Basis For Determination

Of An Elliptical Line Of Position

2.4 Ambiguity of Target Position.

When only two lines of position are used to determine the position of a submerged target, the plot will show an ambiguity of position. This fact is illustrated in Figure 7. This ambiguity could be resolved by another line of position but the explosive echo ranging system for helicopters to be proposed in the next chapter uses only two lines of position. Therefore, an ambiguity will exist whenever the target position is plotted.

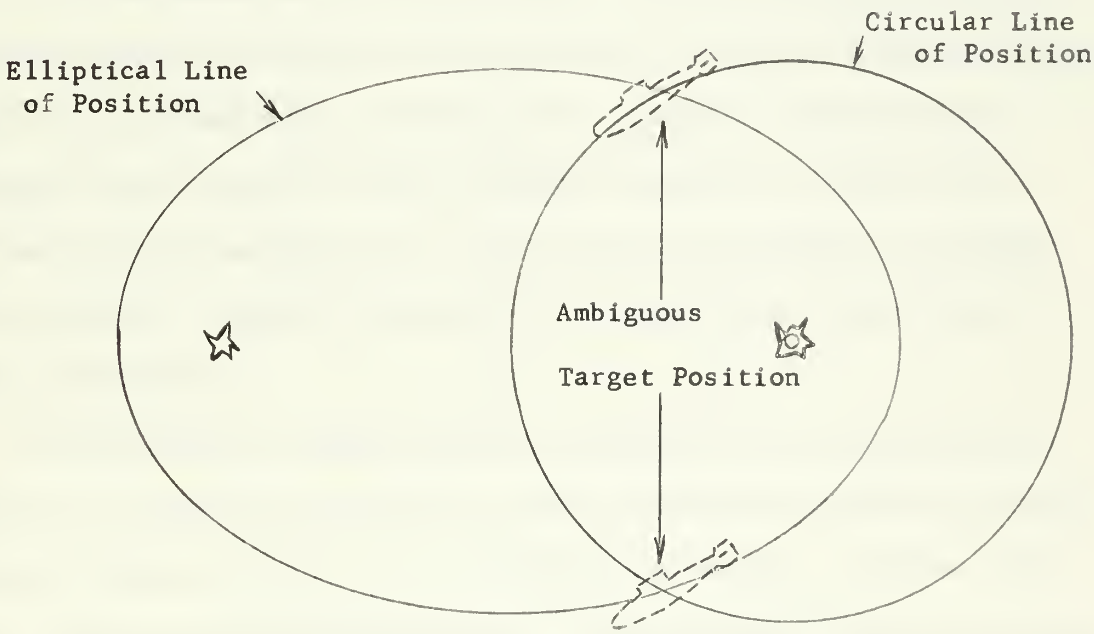

Figure 7

Ambiguity of Target Position

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III

CONCEPT APPLIED TO HELICOPTERS

3.1 The Basic System.

The basic explosive echo ranging system envisioned for helicopter use would consist of a hydrophone, an amplifier, a recorder, and the explosive charges. Lines of position would be plotted manually on a plotter which will be described in a later section.

The hydrophone would be expendable. The wire from the hydrophone assembly would be attached to the amplifier by a quick disconnect device which could be manually or electrically operated. The hydrophone assembly would consist of the hydrophone, associated wiring, and a container which would act as a float when the hydrophone was dropped into the water. Figure 8 illustrates the hydrophone assembly and its mode of deployment.

The hydrophone assembly would be dropped from the helicopter at hover. On striking the water the spring release would allow the hydrophone to deploy, sinking to its predetermined depth. The float would also give the pilot of the helicopter a position over which to hold his hover. When ready to leave the position of search, the quick release would be activated and the hydrophone jettisoned. Eventually the water soluble plug would desolve and the entire assembly would sink.

The helicopters would work in pairs, with one assigned as section leader and the other as wingman. The wingman would take up a position on a designated bearing from the section leader at a predetermined

distance which would be on the order of 4,000 to 6,000 yards. During an area search this position would remain the same throughout the flight.

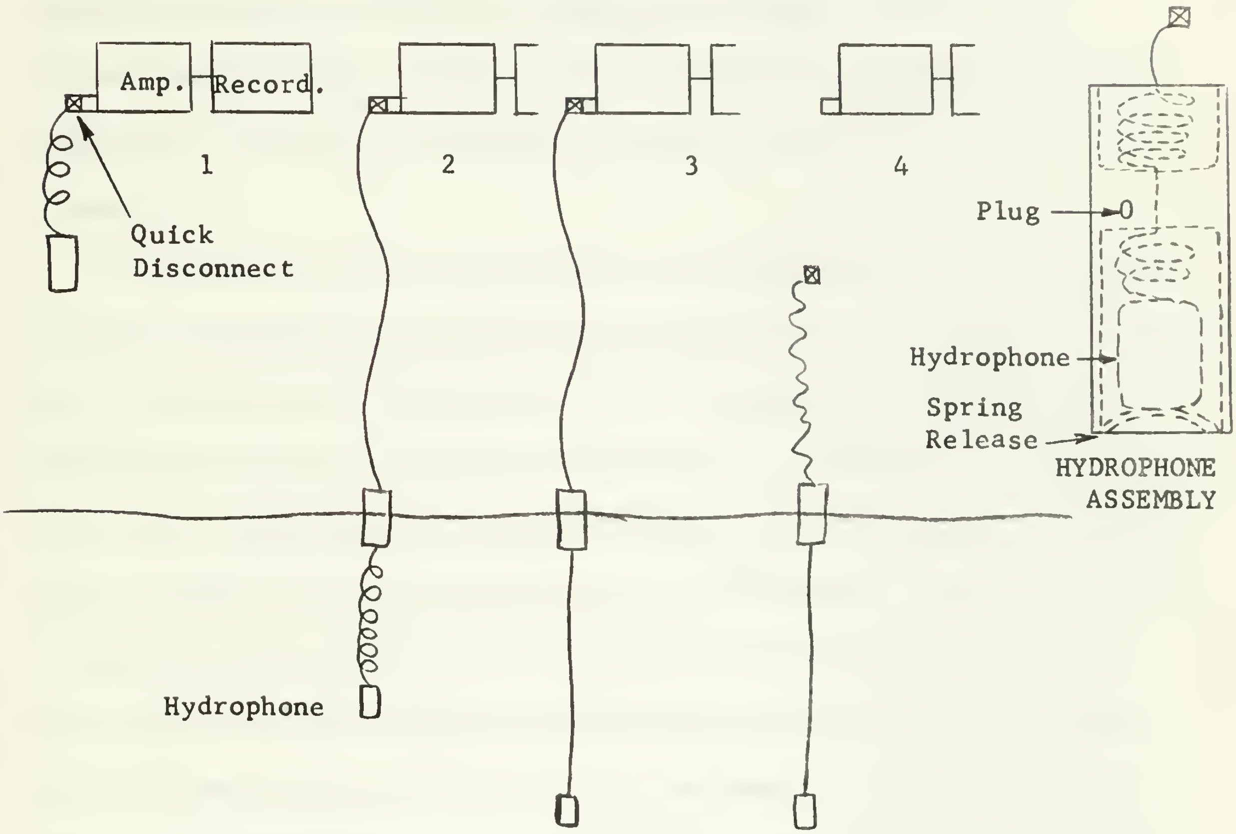

Figure 8

Hydrophone Assembly And Its Deployment

The helicopters would establish a hover and each drop a hydrophone assembly. Simultaneously the section leader would release an explosive charge. If a target echo is received it is plotted as a circular line of position by the section leader and as an elliptical line of position by the wingman. As explained in Section 2.1 the charge would be an on-top drop for the flight leader and an offset drop for the wingman. As

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soon as the wingman records the direct echo from the flight leader's explosive charge, he releases an explosive charge. In the event a target echo is again received, it is plotted as an elliptical line of position by the flight leader and a circular line of position by the wingman.

The intersection of the circular and elliptical lines of position indicate the ambiguous position of the submarine as explained in Section 2.4. To resolve this ambiguity, both helicopters could move forward a prescribed distance, possibly on the order of 1,000 yards and again each drop a hydrophone and charge. Another set of ambiguous positions would indicate the actual position of the submarine. Another method to resolve the orignal ambiguity of target position would be to rotate the axis of the plot by having the helicopters move in opposite directions and again going through the drop sequence. Another target plot would similarly resolve the ambiguity. The former method is presented in Figure 9.

Many other tactics would be necessary to cope with the various combinations of possible target echo plots. As an example a tactic would have to be devised for use when only one line of position was plotted. At this time it may be desirable to repeat the drop sequence in the same position in the hope of obtaining two lines of position on the second drop. This thesis is not attempting to present a full set of tactics for use with helicopter explosive ranging but rather to indicate some possible operational procedures to be investigated if the concept proves tactically feasible.

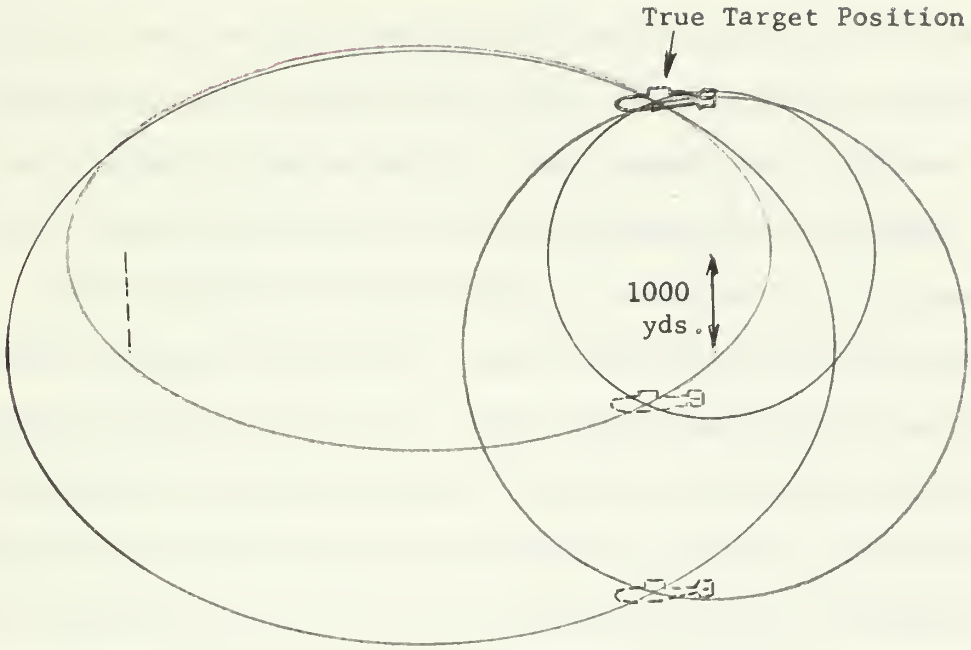

Figure 9

Resolution Of Target Position Ambiguity

3.2 The Nemo Plotter.

As indicated in Section 3.1, the lines of position would be plotted manually by the helicopter JULIE operator. For want of a better name this plotter will be referred to as the "Nemo Plotter". A possible configuration of this plotter is presented as Appendix I. Circular and elliptical lines of position are indicated for both foci positions. To use, the operator has merely to indicate the intersection points of the recorded lines of position as obtained from the recording unit. A separate Nemo Plotter will be required for each different separation distance between helicopters. The plotter shown is predicated on a separation distance of 6,000 yards. It is felt that three separation distances, namely 4,000, 5,000 and 6,000 yards would com-

pletely cover the operational range of the system. As depicted, the plot is a relative position plot. If the bearing cards for each foci position were made movable this plotter could be made to indicate a true or magnetic plot as desired. Only operational experience will dictate which plot would be the most advantageous to maintain.

Many variables will enter into the selection of the separation distance between helicopters. Water conditions will dictate maximum possible ranges of detection. These water conditions can easily be determined by the helicopters by lowering a lightweight bathythermograph to record the temperature profile of the water being searched. [6] From this profile the most desirable separation distance can be determined.

3.3 Operational Utilization Oı The System.

As proposed, the helicopter explosive echo ranging system will be an extremely lightweight system and therefore capable of being adapted to small, lightweight, turbine powered helicopters. This possibility greatly reduces the initial cost of equipment and substantially decreases the operating costs. Consideration could be given to using helicopters currently under development for the Army light observation helicopter (LOH) program. These craft are being designed to have a high degree of reliability and an improved maintenance capability. Their size and ruggedness would permit them tc operate from carrier decks and from helicopter landing decks on smaller combatant ships or auxilliary vessels. Since no elaborate electronic equipment would be involved, the system could be maintained by a relatively small maintenance group.

Helicopter explosive echo ranging would be suitable for screening of naval units or convoy groups as well as area search or datum search. Appendix II illustrates a screening plan for possible use. Several basic assumptions have been made and shall be described in order to explain the basic formulation of the plan.

It is well understood that whenever search is carried out in discrete time intervals, such as helicopter dipping sonar with its dead time between dips due to transit time to next dip position, the area of swept water decreases radially as a direct function of the target submarines possible courses and speeds. However, if an assumption can be made as to the course of the submarine and its maximum speed, the area of swept water does not decrease but is only displaced along the submarines course a maximum distance of submarine speed times the dead time. This is the limiting case and any actual submarine speed less that the maximum will only increase the overlap of swept water from one dip position to the next.

In formulating the screening plan of Appendix II, it has been assumed the submarine would be attempting to approach the screened unit and also attempting to minimize his transit time through the screening units. Therefore, a course opposite to the direction of advance is assumed for the submarine. A maximum speed capability of 15 kts. is also assigned the submarine. The dashed lines indicate the movement of the searched water area during each dip cycle.

As previously explained, the distance between cooperating helicopters would be a function of the maximum detection range of the system under the existing water conditions. For Appendix B this separation distance is assumed as 6,000 yards and the reliable detection range

as 4,000 yards. The dip cycle length, speed of advance (SOA) and distance of advance per dip cycle, jump bearing and distance, and width of screening front are indicated on each search plan.

Since most of the dip cycle time is dead time during transit from one dip position to the next, it is possible for two or more groups of two helicopters to operate together without causing interference as long as one group searches while the other group or groups are in transit to their next dip positions. Appendix II illustrates only the use of two groups of two helicopters each.

As indicated, the jump bearing is the angle between the direction of advance of the search and the direction to the next dip position. The advance per dip cycle is the distance made good in the direction of advance during a dip cycle. Speed of advance is, therefore, the product of advance per dip cycle in yards multiplied by the number of dips per hour divided by 2,000.

Appendix III is a table of values of various parameters that apply to different speeds of advance. The average dip cycle time has been selected from a very pessimistic viewpoint using the generally accepted instrument or night time acceleration and deceleration limits. Appendix IV shows the calculations used to arrive at the dip cycle times. Under flight conditions allowing visual contact with the water, these dip cycle times could be shortened considerably and, therefore, the speed of advance for each particular relative jump bearing and jump distance combination could be increased.

It has been found that submarine positions obtained by explosive echo ranging by fixed wing aircraft are not accurate enough for deploy-

ment of present homing weapons [1]. This necessitates a MAD conversion to provide the fix accuracy necessary for a successful weapon drop. Although the helicopter system should provide more accurate fixes than the fixed wing system, it shall be assumed that a more accurate local-lizer will be required to successfully attack a submarine previously detected by explosive echo ranging.

A logical solution would be to equip each explosive echo ranging helicopter with lightweight MAD equipment in order to be able to pursue the final attack phase. However, no such lightweight equipment is currently operational. If such a system does become available it would integrate readily into this proposed helicopter explosive echo ranging system.

A second possibility is the use of a larger, sonar equipped helicopter(HSS-2) to accurately locate the submarine for a homing weapon attack. This larger helicopter could be in a standby status or actually airborne over the screen. The necessity for prompt classification and immediate attack may preclude the standby status, depending on the time available for killing a submarine before it is in a position to place the screened units under attack.

The problem of classifying a contact has always been a major one. If this function is accomplished by the screening units it usually destroys the integrity of the screening plan and thus leaves areas unsearched. Therefore, if all initial contacts can be classified by a unit not assigned as a screening unit, the integrity of the screen can be maintained. The use of a sonar equipped helicopter to accomplish

this classification, as well as pinpointing the submarine for attack, relieves the screening units of these functions. Another use for the sonar helicopter would be to fill in the screen position of any explosive echo ranging helicopter that made an unscheduled departure from the screen. This action would fill the gap until a standby status, explosive echo ranging helicopter could reach the vacated screen position.

To illustrate the use of the entire concept, we can apply it to the protection of a convoy. Twelve explosive echo ranging helicopters and three HSS-2 type would be assigned to the convoy and would be deployed aboard various ships. (It is conceivable however, that a ship of the AVR type could accommodate all the helicopters needed to protect a convoy).

Four explosive echo ranging helicopters would be assigned to the screen. Assuming a required speed of advance of 12 knots, the screening plan would indicate a relative jump bearing of 65° and a jump distance of 4,000 yards, which would give a screen front of 32,000 yards. The average dip cycle time would be 4.3 minutes which would allow 14 dips per hour.

An HSS-2 would be assigned to the screen as investigator and would maintain a position in close proximity to the screen. Another explosive echo ranging helicopter, without a supply of explosive charges or hydrophones aboard, would be loaded with two homing weapons and would be on a standby status.

When a contact is received, the pair of explosive echo ranging helicopters making the contact would resolve the ambiguity of the target

position and report this position to the HSS-2 who would immediately investigate this position with sonar. The weapon carrying helicopter would have been launched as soon as the first contact had been made and would arrive at the contact area by the time the HSS-2 had confirmed the target and classified it as a submarine. The HSS-2 would then vector the weapon carrying helicopter into a position for weapon release. In the event the HSS-2 evaluated the contact as non-submarine, all units would return to their normal mode of operation.

If it proved too time consuming to have the weapon carrying helicopter on standby status, it is possible to assign two HSS-2's to act as investigators and weapon carriers. They could then also be used to extend the screen front during the time they were not investigating contacts by taking up dip stations on the flanks of the explosive echo ranging screening units. Using this procedure the two HSS-2's would jointly classify the contact and carry out attacks on any contact classified as submarine.

3.4 Possible Problem Areas.

In fixed-wing aircraft explosive echo ranging the hydrophone does not receive any noise from the aircraft because of the distances involved and the small value of the transmission coefficient at the air-sea interface. However, when a helicopter hovers directly over the receiving hydrophone, a significant noise level is produced at the hydrophone due to the noise transmitted into the water. This noise level is usually considerably greater than the existing ambient sea noise [5] and, therefore, can mask the reflected echo received from a contact.

Of course, this problem exists for helicopter sonar as well as helicopter explosive echo ranging systems. The solution is a directional hydrophone whose response in the vertical direction is reduced considerably over its response in the horizontal direction. A suitable hydrophone for explosive echo ranging must have its response to helicopter noise lower than its response to ambient sea state zero noise in order not to be self noise limited.

Since the vehicle proposed for the helicopter explosive echo ranging system is a small, turbine powered craft, the noise level at the hydrophone will be much less than that caused by the much larger, heavier, sonar equipped helicopters. Therefore, this problem should not be as severe as it is in helicopter sonar and should be solvable by use of a relatively inexpensive directional hydrophone. An added benefit of using a hydrophone which is directional in the horizontal plane is the possibility of receiving returns from targets at a distance greater than the depth of the water [8]. This is possible because of the lower response of the hydrophone to bottom return.

To increase the ability of the system to receive target returns from the bottom occlusion area even more, directional explosive charges have been investigated [4] [12]. Tests indicate that the use of a directional charge can increase the detection range of an explosive echo ranging system when this range is bottom-return limited.

The ability of the small, explosive echo ranging helicopter to operate during extremely bad weather can not be estimated. However, for the system to be operationally useful, it must have the ability to

operate during periods of poor weather and during periods of darkness. Only operational tests will be able to ascertain this capability.

Many other problems will become evident during the period of testing of this helicopter explosive echo ranging concept. This writer believes all of them to have logical solutions and that this concept can be an operationally useful system when developed to its optimum potential.

IV

PROCEDURE FOR TESTING CONCEPT

4.1 Initial Feasibility Test

All the equipment necessary for the initial test is currently available. Any helicopter could be used, but one whose noise output closely approximates that of the proposed type would be most suited.

An AN/SSQ-26 sonobuoy would provide the directional hydrophone assembly and the first stage of amplification of the hydrophone output. For the first tests the power supply of the AN/SSQ-26 can be used but later a more stable, integrated power supply and amplifier would be necessary. An AN/ASA-20 Recorder Group would provide means for determining the circular and elliptical lines of position of a target. Another amplifier may be required just ahead of the recorder group to raise the output of the hydrophone to a suitable level for the recorder group.

The recorder has dual channel Sanborne movements, which use heated styli for writing on heat sensitive paper. Time intervals between the direct explosion and echoes are measured by means of cursors on the face of the recorder. Since only one channel is required for the proposed helicopter system, it is suggested that the output of the single hydrophone be fed to both channels, but that different filters be used in each channel. One channel could use a 1/3 octave filter [8] to increase the horizontal directivity of the system, while the other channel could use the standard 1 to 3 kc. filter. It is, therefore, possible to receive an echo on one time trace that is masked by noise or

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bottom return on the other trace. This feature would increase the probability of receiving an echo when a target is within the systems range capability.

The explosive sound sources presently used in fixed-wing explosive echo ranging are suitable for the initial test phase [7]. Both the Mk-15 Mod 1 Practice Depth Charge (PDC) and Mk-50 Mod 0 Signal Underwater Sound (SUS) should be tested to see if the extra charge of the Mk-50 significantly increases the range of detection.

A "Nemo Plotter" can be fabricated locally with a minumum amount of labor. Instead of separate plotters for each variable distance between cooperating helicopters, it may be possible to use a single plotter with overlays for each particular separation distance.

This interim system would then have to be tested under controlled conditions to determine the feasibility of the concept. During the tests the cooperating helicopter would not have to be equipped with any system equipment. It would merely act as an offset drop point by releasing explosive charges at the points designated. During the initial test phase the hydrophone unit would not be expendable since the time delay of lowering and raising the hydrophone would be acceptable.

In the event the vertical rejection of the AN/SSQ-26 hydrophone is not sufficient to reduce the helicopter noise to a suitable level, it may be necessary to replace this unit with a hydrophone from an AN/AQS-10 helicopter sonar in order to complete the initial tests. It is realized that this hydrophone is much too expensive in its present form to be used as an expendable unit for helicopter explosive echo ranging.

However, it would be suitable to use during the feasibility tests. A suitable, inexpensive hydrophone assembly can be developed to meet the needs of the proposed system.

4.2 Design of Operational System

From the data gathered during the initial test phase it would be possible to design the lightweight system envisioned in this thesis. If this system were designed around the AN/ASA-20 Recorder Group, the total weight would be on the order of 400 pounds as outlined below:

AN/ASA-20 (currently available)	60 lbs
Quick disconnect and amplifier (to be developed)	20
30 Modified AN/SSQ-26 hydrophones (currently available)	90
40 MK-50 MOD 0 SUS at 5 lbs. ea. (currently available)	200
	370 lbs

Any change of hydrophone or explosive charge type is readily adapted to this system since both of these units are expendable. Neither change would require any retrofit of the original equipment.

If desired, the entire explosive echo ranging package could be made into a single unit that could easily be installed or removed from the helicopter. This would allow the rapid conversion of any small helicopter to an explosive echo ranging helicopter or would allow assigned explosive echo ranging helicopters to be used for other purposes.

Furture development of a device which would eliminate the need for helicopters to work in pairs is a natural evolution for this system. A method of allowing a helicopter to position its own offset charges would give it the capability of generating both circular and elliptical

lines of position without a cooperating helicopter. The Army is currently evaluation a 40-mm. XM-75 grenade launcher in conjunction with evaluation tests of the Bell OH-4A, light observation helicopter [1[illegible]]. A second generation device of this type could give an explosive echo ranging helicopter the capability of positioning its own offset charges. Figure 10 illustrates a possible charge pattern which could be employed.

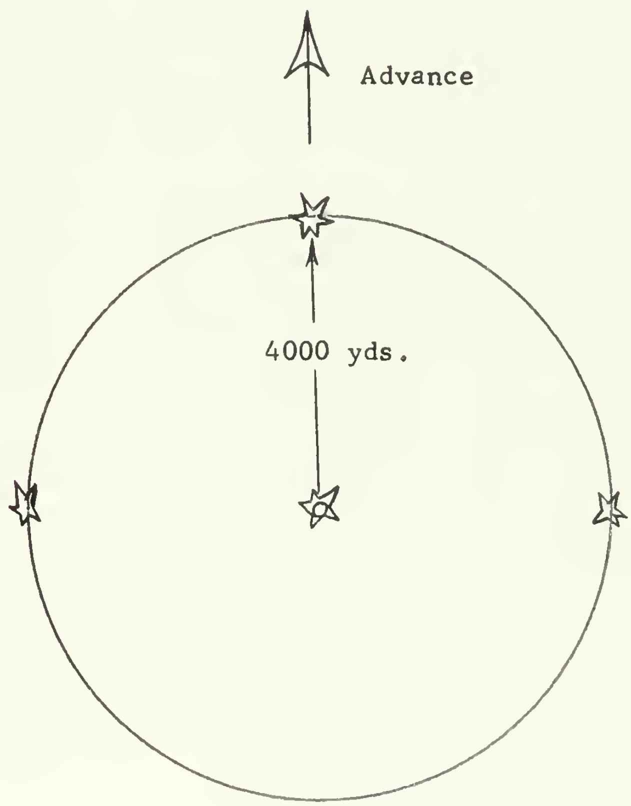

Figure 10

Single Helicopter Charge Pattern

The direct occlusion area associated with any offset charge is covered by the area of detection capability associated with one of the other offset charges. Therefore, all the area is covered by the four-

[illegible]

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[illegible]

charge combination. Another advantage to this method is that the intersection of any three lines of position uniquely determines the position of the submarine.

V

SUMMARY AND CONCLUSIONS

5.1 General Comments

There is no question as to the ability of explosive echo ranging to successfully locate submarines. For years this system has been used by fixed wing aircraft as a primary means of initial detection of submerged submarines. It is an active system that can locate an enemy even when he is not cavitating. His presence within the range limitations of the system subjects him to being detected regardless of his evasive tactics.

This thesis is not proposing another detection device, but only another use for a proven system. Many of the problems associated with fixed wing aircraft use of explosive echo ranging are not present in the helicopter system. This allows a more simplified version to meet the requirements set down for any detection system. This simplified version is considerably lighter than such systems as dunking sonar and, therefore, lends itself to use by smaller and less expensive helicopters. It is an attempt to reverse the trend to more sophisticated, expensive weapon systems, with their attendant problem of maintainability. It is not necessarily true that the most expensive method is always the best.

VI

RECOMMENDATIONS

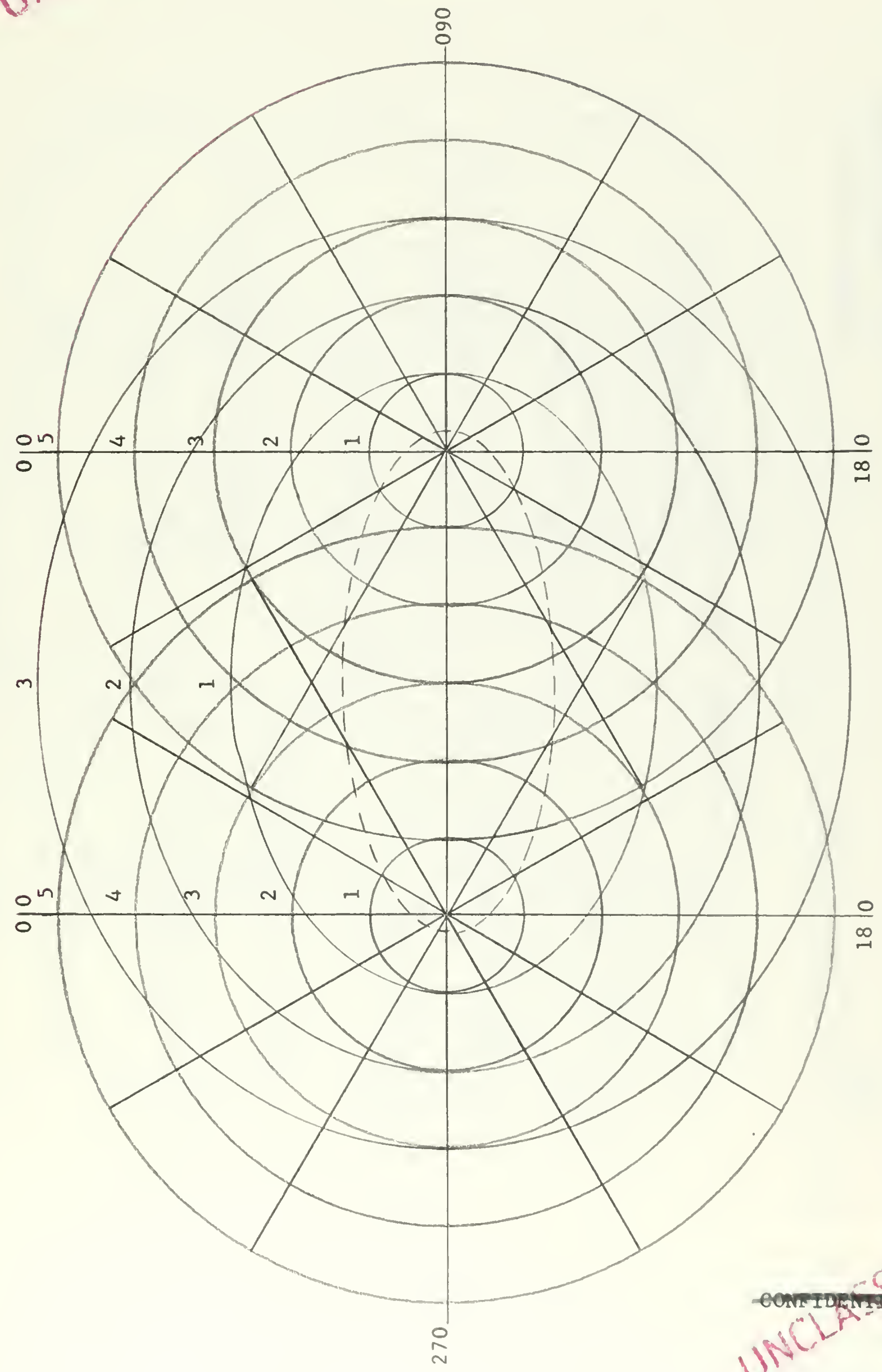
6.1 Recommendations

This thesis assumes that the only real question about use of explosive echo ranging by helicopters is the selection of the optimum method of application. Along with this assumption the following recommendations are made:

1. Make a feasibility test of the concept as suggested in this thesis or as other considerations dictate.
2. Initiate theoretical studies as to the detection probabilities associated with various search methods.
3. Select from among available or proposed helicopters that one which can most fully exploit the potential of explosive echo ranging.
4. Design a simple, lightweight helicopter explosive echo ranging system compatible with the helicopter selected and with the operational requirements it must fulfill.
5. Delineate operational tactics to be investigated prior to the introduction of the system into operational use.

APPENDIX I

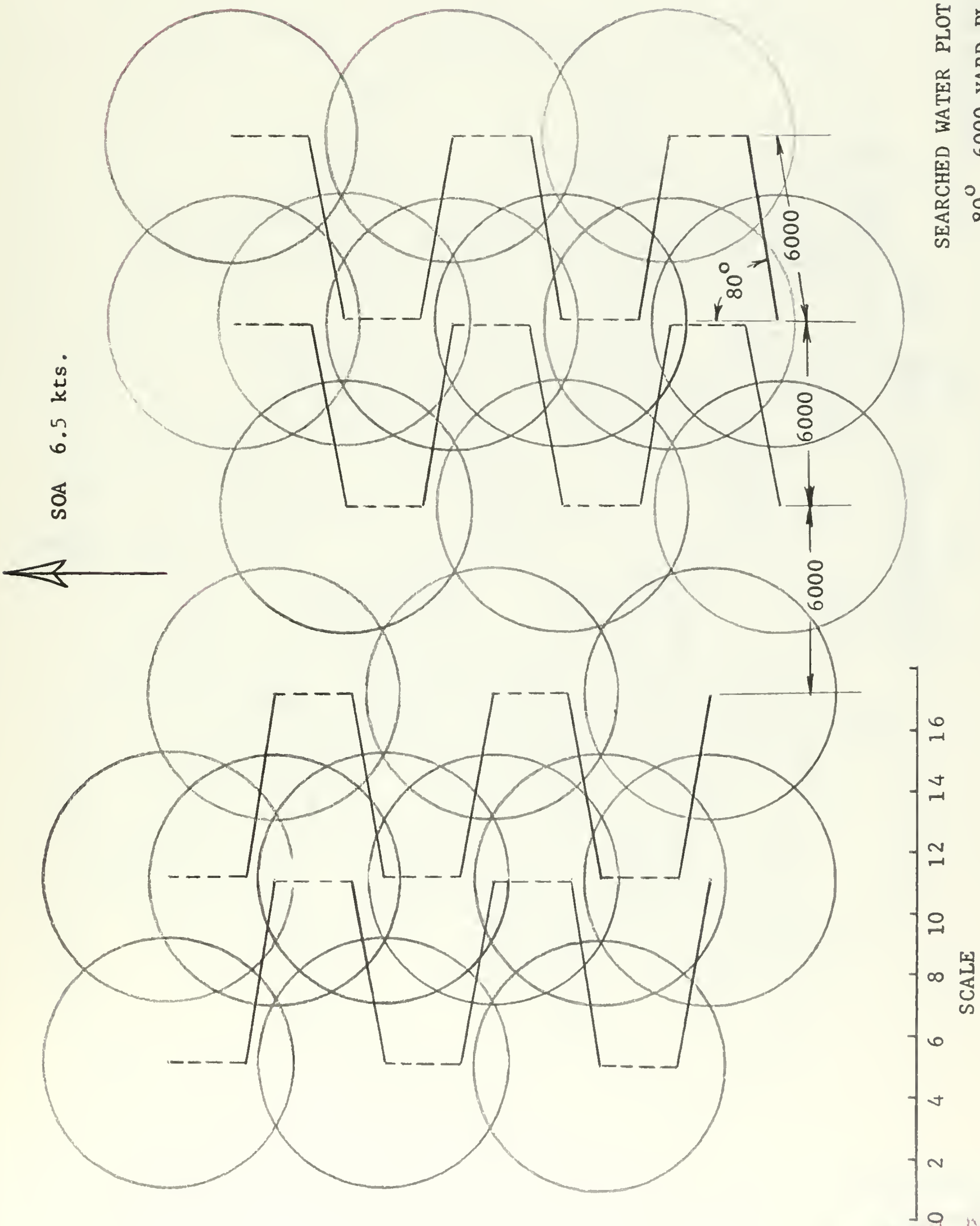
6000 YARD NEMO PLOTTER



CONFIDENTIAL

UNCLASSIFIED

APPENDIX II

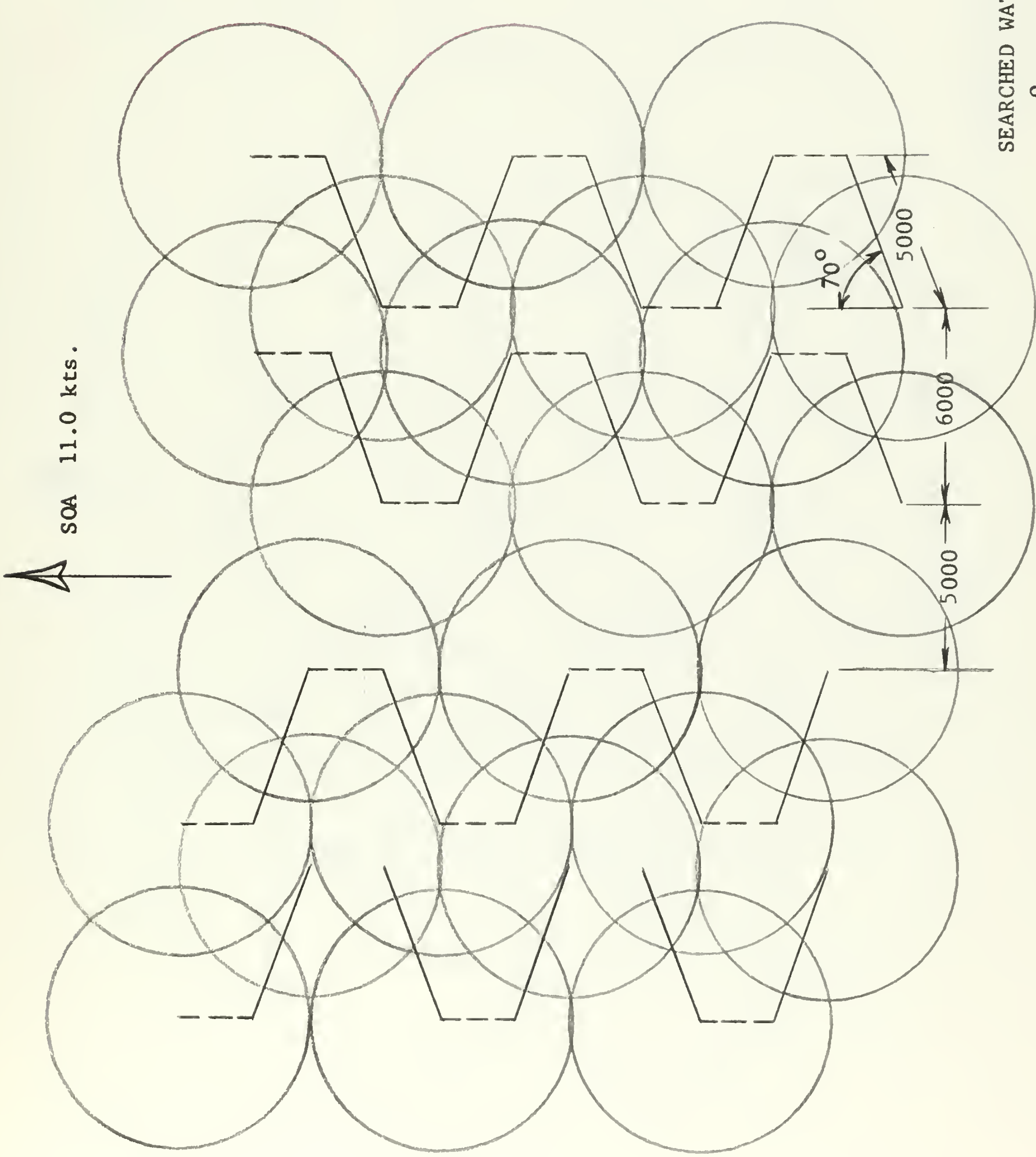


SEARCHED WATER PLOT

80° 6000 YARD PLAN

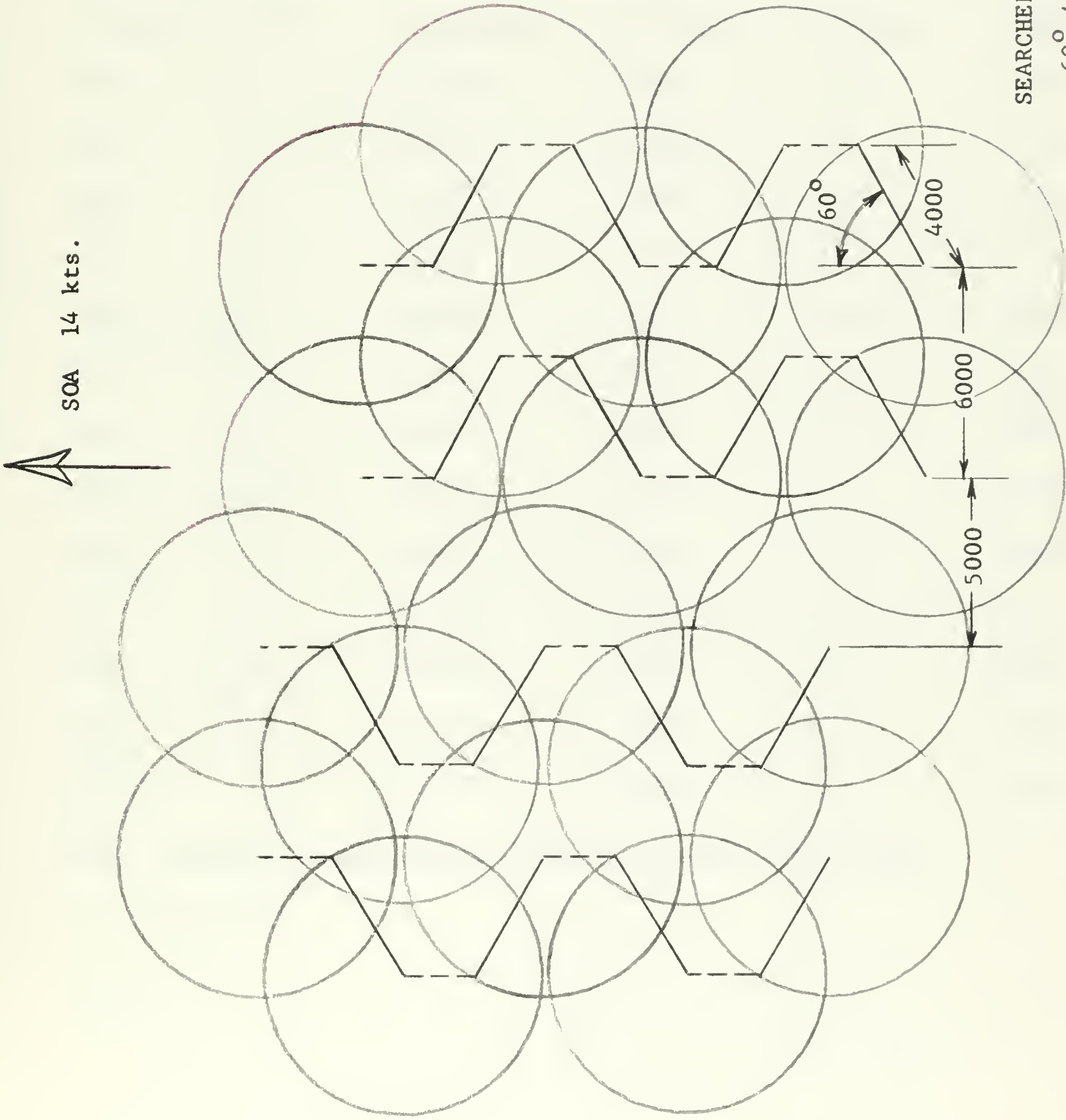
UNCLASSIFIED

CONFIDENTIAL



SEARCHED WATER PLOT
70^{o} 5000 YARD PLAN

SEARCHED WATER PLOT
60° 4000 YARD PLAN



APPENDIX III

SCREENING PLANS

Speed of Advance	Relative Jump Bearing	Distance Between Groups	Jump Distance	Average Dip Cycle	Screen Front
6.5 kts.	80°	6,000 yds.	6,000 yds.	5.0 min.	35,000 yds.
9.5	75	6,000	6,000	5.0	34,000
11.0	70	5,000	5,000	4.6	33,000
12.0	65	5,000	4,000	4.3	32,000
14.0	60	5,000	4,000	4.3	31,000
16.0	55	5,000	4,000	4.3	29,500
18.0	50	5,000	4,000	4.3	28,000
19.5	45	5,000	4,000	4.3	27,000
21.5	40	5,000	4,000	4.3	27,000
23.0	35	5,000	4.000	4.3	26,500
24.5	30	5,000	4.000	4.3	26,500
26.0	20	5,000	4,000	4.3	26,000
27.0	10	5,000	4,000	4.3	25,500
28.0	0	6,000	4,000	4.3	25,000

Note: Distance Between Cooperating Helicopters 6,000 Yards.

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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APPENDIX IV

DIP CYCLE TIME CALCULATION

The calculations below are made using the following assumptions:

1. A 90 kt. cruise helicopter
2. Acceleration: 2 kts/sec
3. Deceleration: 2 kts/sec to 50 kts
   1 kt/sec below 50 kts

	Time	Distance Covered
Acceleration	45 sec	1,120 yards
Deceleration	20	780
	50	700
	115 sec	2,600 yards

6,000 Yard Jump

Acc. & Dec.	115 sec	2,600 yards
Cruise	70	3,400
Hover	115	
	5 min.	6,000 yards

5,000 Yard Jump

Acc. & Dec.	115 sec	2,600 yards
Cruise	50	2,400
Hover	110	
	4.6 min	5,000 yards

4,000 Yard Jump

Acc. & Dec.	115 sec	2,600 yards
Cruise	30	1,400
Hover	115	
	4.3 min	4,000 yards

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